AI LAB RECORD

LAB 1: Implement Tic –Tac –Toe Game.

CODE:

```
board = [' ' for x in range(10)]
def printBoard(board):
    print(' ' + board[1] + ' | ' + board[2] + ' | ' + board[3])
    print('-----------')
    print(' ' + board[4] + ' | ' + board[5] + ' | ' + board[6])
    print('-----------')
    print(' ' + board[7] + ' | ' + board[8] + ' | ' + board[9])
def isBoardFull(board):
    if board.count(' ') > 1:
        return False
    else:
        return True
def insertLetter(letter, pos):
    board[pos] = letter
def spaceIsFree(pos):
    return board[pos] == ' '
def isWinner(bo, le):
    return (bo[7] == le and bo[8] == le and bo[9] == le) or (bo[4] == le and bo[5] == le and
bo[6] == le) or (
            bo[1] == le and bo[2] == le and bo[3] == le) or (bo[1] == le and bo[4] == le and bo[7]
== le) or (
                bo[2] == le and bo[5] == le and bo[8] == le) or (
                bo[3] == le and bo[6] == le and bo[9] == le) or (
```

```
                bo[1] == le and bo[5] == le and bo[9] == le) or (bo[3] == le and bo[5] == le and
bo[7] == le)
def playerMove():
    run = True
    while run:
        move = input('Please select a position to place an \'X\' (1-9): ')
        try:
            move = int(move)
            if move > 0 and move < 10:
                if spaceIsFree(move):
                    run = False
                    insertLetter('X', move)
                else:
                    print('Sorry, this space is occupied!')
            else:
                print('Please type a number within the range!')
        except:
            print('Please type a number!')
def selectRandom(li):
    import random
    ln = len(li)
    r = random.randrange(0, ln)
    return li[r]
def compMove():
    possibleMoves = [x for x, letter in enumerate(board) if letter == ' ' and x != 0]
    move = 0

    for let in ['O', 'X']:
        for i in possibleMoves:
            boardCopy = board[:]
```

```
            boardCopy[i] = let
            if isWinner(boardCopy, let):
                move = i
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\TIC_TAC.py"
Do you want to play? (Y/N)Y
-----------------------------------
Welcome to Tic Tac Toe!
   |   |
-----------
   |   |
-----------
   |   |
Please select a position to place an 'X' (1-9): 1
 X |   |
-----------
   |   |
-----------
 O |   |
Computer placed an 'O' in position 3 :
 X | X | O
-----------
   |   |
-----------
 O |   |
Please select a position to place an 'X' (1-9): 5
 X | X | O
-----------
   | X |
-----------
 O |   |
Computer placed an 'O' in position 8 :
 X | X | O
-----------
   | X |
-----------
 O | O |
Please select a position to place an 'X' (1-9): 9
 X | X | O
-----------
   | X |
-----------
 O | O | X
X's won this time! Good Job!
```

LAB 2: Solve 8 puzzle problem.

CODE:

```
def printpuzzle(src):
    print(' ' + src[0] + ' | ' + src[1] + ' | ' + src[2])
    print('-----------')
    print(' ' + src[3] + ' | ' + src[4] + ' | ' + src[5])
    print('-----------')
    print(' ' + src[6] + ' | ' + src[7] + ' | ' + src[8])
    print('\n')
def bfs(src,target):
    queue = []
    queue.append(src)

    explored = []

    while len(queue) > 0:
        source = queue.pop(0)
        explored.append(source)

        printpuzzle(source)

        if source==target:
            print("Goal State Reached")
            return

        poss_moves_to_do = []
        poss_moves_to_do = possible_moves(source,explored)

        for move in poss_moves_to_do:
            queue.append(move)
```

```
def possible_moves(state,visited_states):
    b = state.index(' ')
    dir = []
    if b not in [0,1,2]:
        dir.append('u')
    if b not in [6,7,8]:
        dir.append('d')
    if b not in [0,3,6]:
        dir.append('l')
    if b not in [2,5,8]:
        dir.append('r')



    pos_moves= []



    for i in dir:
        pos_moves.append(convert(state,i,b))

    return [move for move in pos_moves if move not in visited_states]
def convert(state, m, b):
    temp = state.copy()

    if m=='d':
        temp[b+3],temp[b] = temp[b],temp[b+3]

    if m=='u':
        temp[b-3],temp[b] = temp[b],temp[b-3]
```

```
    if m=='l':
        temp[b-1],temp[b] = temp[b],temp[b-1]

    if m=='r':
        temp[b+1],temp[b] = temp[b],temp[b+1]


    return temp
src = ['1','2','3',' ','4','5','6','7','8']
target = ['1','2','3','4','5',' ','6','7','8']
bfs(src, target)
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\8puzzle_BFS.py"
 1 | 2 | 3
-----------
   | 4 | 5
-----------
 6 | 7 | 8


   | 2 | 3
-----------
 1 | 4 | 5
-----------
 6 | 7 | 8


 1 | 2 | 3
-----------
 6 | 4 | 5
-----------
   | 7 | 8


 1 | 2 | 3
-----------
 4 |   | 5
-----------
 6 | 7 | 8


 2 |   | 3
-----------
 1 | 4 | 5
-----------
 6 | 7 | 8
```

LAB 3: Implement Iterative deepening search algorithm.

CODE:

```
def dfs(src,target,limit,visited_states):
    if src == target:
        return True
    if limit <= 0:
        return False
    visited_states.append(src)
    moves = possible_moves(src,visited_states)
    for move in moves:
        if dfs(move, target, limit-1, visited_states):
            return True
    return False
def possible_moves(state,visited_states):
    b = state.index(-1)
```

```
    d = []
    if b not in [0,1,2]:
        d.append('u')
    if b not in [6,7,8]:
        d.append('d')
    if b not in [2,5,8]:
        d.append('r')
    if b not in [0,3,6]:
        d.append('l')
    pos_moves = []
    for move in d:
        pos_moves.append(gen(state,move,b))
    return [move for move in pos_moves if move not in visited_states]
def gen(state, move, blank):
    temp = state.copy()
    if move == 'u':
        temp[blank-3], temp[blank] = temp[blank], temp[blank-3]
    if move == 'd':
        temp[blank+3], temp[blank] = temp[blank], temp[blank+3]
    if move == 'r':
        temp[blank+1], temp[blank] = temp[blank], temp[blank+1]
    if move == 'l':
        temp[blank-1], temp[blank] = temp[blank], temp[blank-1]
    return temp
def iddfs(src,target,depth):
    for i in range(depth):
        visited_states = []
        if dfs(src,target,i+1,visited_states):
            return True
```

```
    return False
src = [1, 2, 3, 4, 5, 6, 7, 8, -1]
target = [-1, 1, 2, 3, 4, 5, 6, 7, 8]

for i in range(1, 100):
    val = iddfs(src,target,i)
    print(i, val)
    if val == True:
        break
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\8puzzle
1 False
2 False
3 False
4 False
5 False
6 False
7 False
8 False
9 False
10 False
11 False
12 False
13 False
14 False
15 False
16 False
17 False
18 False
19 False
20 False
21 False
22 False
23 False
24 False
25 True
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2>
```

LAB 4: Implement A* search algorithm.

CODE:

```
def print_grid(src):
    state = src.copy()
    state[state.index(-1)] = ' '
    print(
        f"""
{state[0]} {state[1]} {state[2]}
{state[3]} {state[4]} {state[5]}
{state[6]} {state[7]} {state[8]}
        """
    )
def h(state, target):
    #Manhattan distance
    dist = 0
    for i in state:
        d1, d2 = state.index(i), target.index(i)
        x1, y1 = d1 % 3, d1 // 3
        x2, y2 = d2 % 3, d2 // 3
        dist += abs(x1-x2) + abs(y1-y2)
    return dist
def astar(src, target):
    states = [src]
    g = 0
    visited_states = set()
    while len(states):
        print(f"Level: {g}")
        moves = []
        for state in states:
```

```
        visited_states.add(tuple(state))
        print_grid(state)
        if state == target:
            print("Success")
            return
        moves += [move for move in possible_moves(state, visited_states) if move not in
moves]
    costs = [g + h(move, target) for move in moves]
    states = [moves[i] for i in range(len(moves)) if costs[i] == min(costs)]
    g += 1
    if g>10:
        print("NO SOLUTION")
        break
def possible_moves(state, visited_states):
  b = state.index(-1)
  d = []
  if 9 > b - 3 >= 0:
    d += 'u'
  if 9 > b + 3 >= 0:
    d += 'd'
  if b not in [2,5,8]:
    d += 'r'
  if b not in [0,3,6]:
    d += 'l'
  pos_moves = []
  for move in d:
    pos_moves.append(gen(state,move,b))
  return [move for move in pos_moves if tuple(move) not in visited_states]
def gen(state, direction, b):
  temp = state.copy()
```

```
    if direction == 'u':
        temp[b-3], temp[b] = temp[b], temp[b-3]
    if direction == 'd':
        temp[b+3], temp[b] = temp[b], temp[b+3]
    if direction == 'r':
        temp[b+1], temp[b] = temp[b], temp[b+1]
    if direction == 'l':
        temp[b-1], temp[b] = temp[b], temp[b-1]
    return temp
src = [8,2,3,-1,4,6,7,5,1]
target = [1,2,3,4,5,6,7,8,-1]

astar(src, target)
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\8puzzle_Astar.p
Level: 0

8 2 3
  4 6
7 5 1

Level: 1

8 2 3
4   6
7 5 1

Level: 2

8 2 3
4 5 6
7   1

Level: 3

8 2 3
4 5 6
7 1

Level: 4

8 2 3
4 5
7 1 6

Level: 5

8 2
4 5 3
7 1 6
```

```
4   5
7 1 6

Level: 6

8 2 3
4 1 5
7   6

Level: 7

8 2 3
4 1 5
7 6

Level: 8

8 2 3
4 1
7 6 5

Level: 9

8 2
4 1 3
7 6 5


8 2 3
4   1
7 6 5

Level: 10

8 2 3
4 6 1
7   5

NO SOLUTION
```

LAB 5: Implement vacuum cleaner agent

CODE:

```
def clean(floor):
    row = len(floor)
    col = len(floor[0])
    for i in range(0, row):
        if(i%2 == 0):
            for j in range(0, col):
                if(floor[i][j] == 1):
                    floor[i][j] = 0
```

```
            print_floor(floor, i, j)
        else:
            for j in range(col-1, -1, -1):
                if(floor[i][j] == 1):
                    floor[i][j] = 0
                print_floor(floor, i, j)

def print_floor(floor, row, col):
    for i in range(0, len(floor)):
        for j in range(0, len(floor[0])):
            if(i == row and j == col):
                print(f"|{floor[i][j]}|", end=" ")
            else:
                print(f" {floor[i][j]} ", end=" ")
        print(end='\n')
    print(end='\n')
def main():
    print("Enter no. of rows")
    m = int(input())
    print("Enter no.of columns")
    n = int(input())
    floor = []
    for i in range(0, m):
        a = list(map(int, input().split(" ")))
        floor.append(a)
    print()
    clean(floor)
main()
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\vaccumecleaner.py"
Enter no. of rows
3
Enter no.of columns
4
1 0 0 0
0 1 0 1
1 0 1 1

|0|  0   0   0
 0   1   0   1
 1   0   1   1

 0  |0|  0   0
 0   1   0   1
 1   0   1   1

 0   0  |0|  0
 0   1   0   1
 1   0   1   1

 0   0   0  |0|
 0   1   0   1
 1   0   1   1

 0   0   0   0
 0   1   0  |0|
 1   0   1   1

 0   0   0   0
 0   1  |0|  0
 1   0   1   1

 0   0   0   0
 0  |0|  0   0
 1   0   1   1

 0   0   0   0
|0|  0   0   0
 1   0   1   1

 0   0   0   0
 0   0   0   0
|0|  0   1   1

 0   0   0   0
 0   0   0   0
 0  |0|  1   1

 0   0   0   0
 0   0   0   0
 0   0  |0|  1

 0   0   0   0
 0   0   0   0
 0   0   0  |0|
```

LAB 6: Create a knowledgebase using prepositional logic and show that the given query entails the knowledge base or not.

CODE:

```
combinations=[(True,True, True),(True,True,False),(True,False,True),(True,False,
False),(False,True, True),(False,True, False),(False, False,True),(False,False, False)]
variable={'p':0,'q':1, 'r':2}
kb=''
q=''
priority={'~':3,'v':1,'^':2}
def input_rules():
    global kb, q
    kb = (input("Enter rule: "))
    q = input("Enter the Query: ")
def entailment():
    global kb, q
    print('*'*10+"Truth Table Reference"+'*'*10)
    print('kb','alpha')
    print('*'*10)
    for comb in combinations:
        s = evaluatePostfix(toPostfix(kb), comb)
        f = evaluatePostfix(toPostfix(q), comb)
        print(s, f)
        print('-'*10)
        if s and not f:
            return False
    return True

def isOperand(c):
    return c.isalpha() and c!='v'
```

```
def isLeftParanthesis(c):
    return c == '('

def isRightParanthesis(c):
    return c == ')'

def isEmpty(stack):
    return len(stack) == 0

def peek(stack):
    return stack[-1]

def hasLessOrEqualPriority(c1, c2):
    try:
        return priority[c1]<=priority[c2]
    except KeyError:
        return False
def toPostfix(infix):
    stack = []
    postfix = ''
    for c in infix:
        if isOperand(c):
            postfix += c
        else:
            if isLeftParanthesis(c):
                stack.append(c)
            elif isRightParanthesis(c):
                operator = stack.pop()
                while not isLeftParanthesis(operator):
```

```
                postfix += operator
                operator = stack.pop()
            else:
                while (not isEmpty(stack)) and hasLessOrEqualPriority(c, peek(stack)):
                    postfix += stack.pop()
                stack.append(c)
    while (not isEmpty(stack)):
        postfix += stack.pop()

    return postfix
def evaluatePostfix(exp, comb):
    stack = []
    for i in exp:
        if isOperand(i):
            stack.append(comb[variable[i]])
        elif i == '~':
            val1 = stack.pop()
            stack.append(not val1)
        else:
            val1 = stack.pop()
            val2 = stack.pop()
            stack.append(_eval(i,val2,val1))
    return stack.pop()
def _eval(i, val1, val2):
    if i == '^':
        return val2 and val1
    return val2 or val1
input_rules()
ans = entailment()
```

```
if ans:
    print("The Knowledge Base entails query")
else:
print("The Knowledge Base does not entail query")
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\N_AI\Entail.py"
Enter rule: (~qv~pvr)^(~q^p)^q
Enter the Query: r
**********Truth Table Reference**********
kb alpha
**********
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
False True
----------
False False
----------
The Knowledge Base entails query
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2>
```

LAB 7: Create a knowledgebase using prepositional logic and prove the given query using resolution

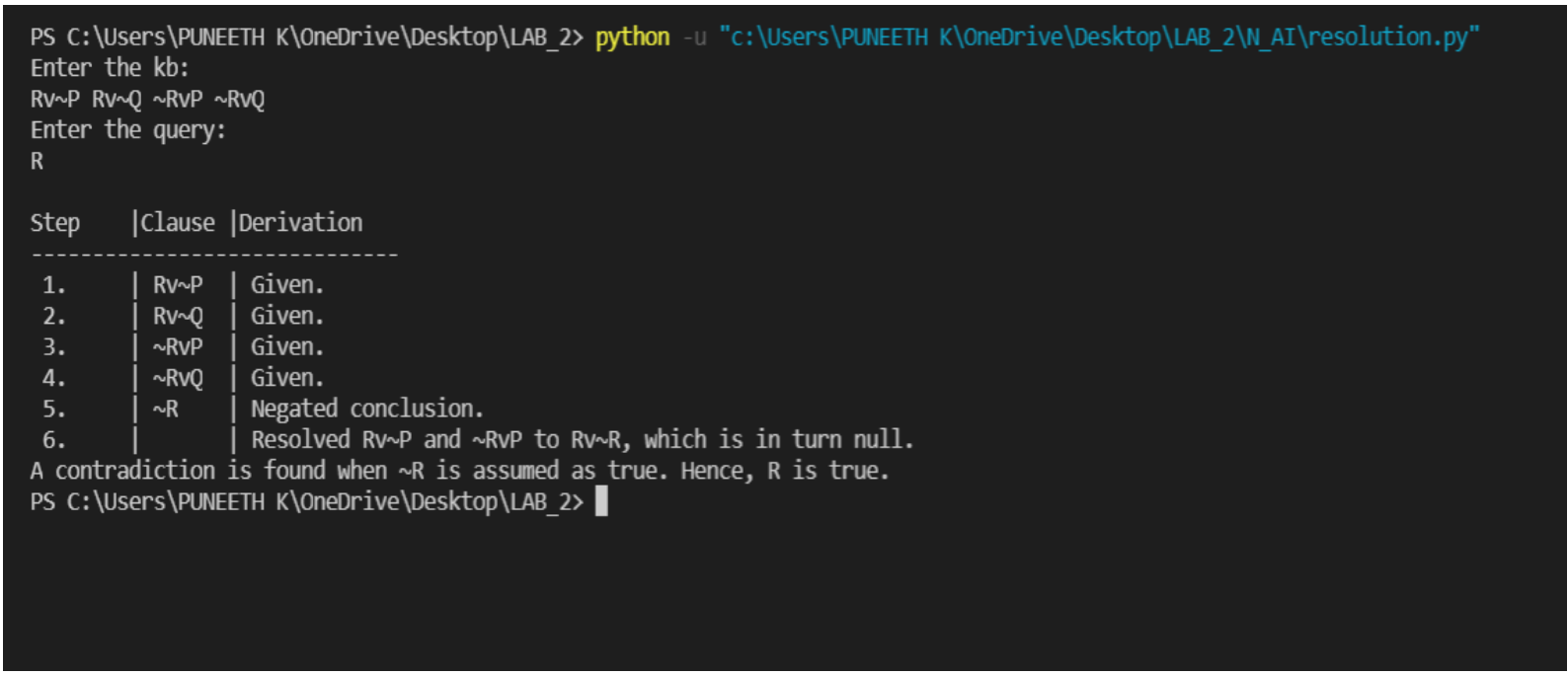
CODE:

```
import re
def negate(term):
    return f'~{term}' if term[0] != '~' else term[1]


def reverse(clause):
    if len(clause) > 2:
        t = split_terms(clause)
        return f'{t[1]}v{t[0]}'
    return ''
def split_terms(rule):
    exp = '(~*[PQRS])'
    terms = re.findall(exp, rule)
    return terms
def contradiction(query, clause):
    contradictions = [ f'{query}v{negate(query)}', f'{negate(query)}v{query}']
    return clause in contradictions or reverse(clause) in contradictions
def resolve(kb, query):
    temp = kb.copy()
    temp += [negate(query)]
    steps = dict()
    for rule in temp:
        steps[rule] = 'Given.'
    steps[negate(query)] = 'Negated conclusion.'
    i = 0
    while i < len(temp):
        n = len(temp)
```

```
    j = (i + 1) % n
    clauses = []
    while j != i:
        terms1 = split_terms(temp[i])
        terms2 = split_terms(temp[j])
        for c in terms1:
            if negate(c) in terms2:
                t1 = [t for t in terms1 if t != c]
                t2 = [t for t in terms2 if t != negate(c)]
                gen = t1 + t2
                if len(gen) == 2:
                    if gen[0] != negate(gen[1]):
                        clauses += [f'{gen[0]}v{gen[1]}']
                    else:
                        if contradiction(query,f'{gen[0]}v{gen[1]}'):
                            temp.append(f'{gen[0]}v{gen[1]}')
                            steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                            \nA contradiction is found when {negate(query)} is assumed as true. Hence, {query} is true."
                            return steps
                elif len(gen) == 1:
                    clauses += [f'{gen[0]}']
                else:
                    if contradiction(query,f'{terms1[0]}v{terms2[0]}'):
                        temp.append(f'{terms1[0]}v{terms2[0]}')
                        steps[''] = f"Resolved {temp[i]} and {temp[j]} to {temp[-1]}, which is in turn null. \
                        \nA contradiction is found when {negate(query)} is assumed as true. Hence, {query} is true."
                        return steps
```

```
            for clause in clauses:
                if clause not in temp and clause != reverse(clause) and reverse(clause) not in temp:
                    temp.append(clause)
                    steps[clause] = f'Resolved from {temp[i]} and {temp[j]}.'
            j = (j + 1) % n
        i += 1
    return steps
def resolution(kb, query):
    kb = kb.split(' ')
    steps = resolve(kb, query)
    print('\nStep\t|Clause\t|Derivation\t')
    print('-' * 30)
    i = 1
    for step in steps:
        print(f' {i}.\t| {step}\t| {steps[step]}\t')
        i += 1
def main():
    print("Enter the kb:")
    kb = input()
    print("Enter the query:")
    query = input()
    resolution(kb,query)
main()
```

OUTPUT:



LAB 8: Implement unification in first order logic

CODE:

```
import re

def getAttributes(expression):
    expression = expression.split("(")[1:]
    expression = "(".join(expression)
    expression = expression.split(")")[:-1]
    expression = ")".join(expression)
    attributes = expression.split(',')
    return attributes


def getInitialPredicate(expression):
    return expression.split("(")[0]
def isConstant(char):
```

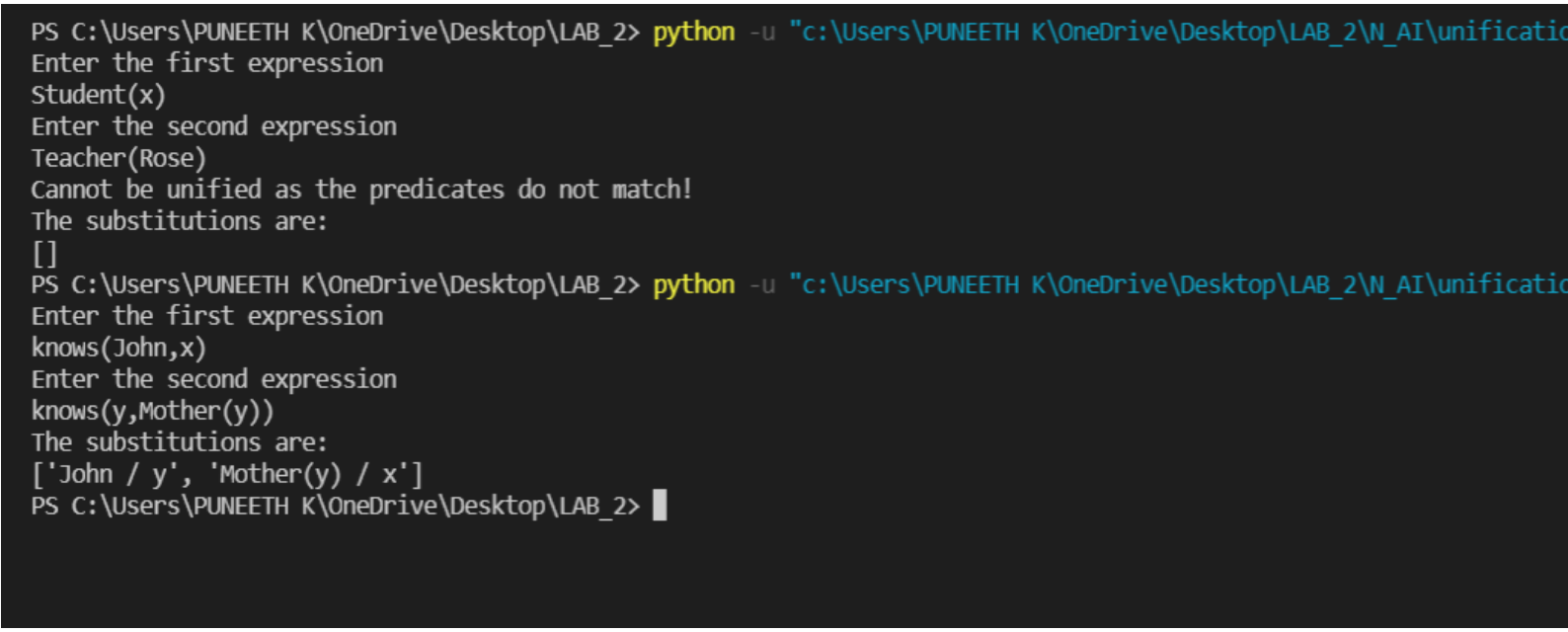
```
    return char.isupper() and len(char) == 1

def isVariable(char):
    return char.islower() and len(char) == 1
def replaceAttributes(exp, old, new):
    attributes = getAttributes(exp)
    predicate = getInitialPredicate(exp)
    for index, val in enumerate(attributes):
        if val == old:
            attributes[index] = new
    return predicate + "(" + ",".join(attributes) + ")"

def apply(exp, substitutions):
    for substitution in substitutions:
        new, old = substitution
        exp = replaceAttributes(exp, old, new)
    return exp
def checkOccurs(var, exp):
    if exp.find(var) == -1:
        return False
    return True


def getFirstPart(expression):
    attributes = getAttributes(expression)
    return attributes[0]


def getRemainingPart(expression):
```

```
    predicate = getInitialPredicate(expression)
    attributes = getAttributes(expression)
    newExpression = predicate + "(" + ",".join(attributes[1:]) + ")"
    return newExpression
def unify(exp1, exp2):
    if exp1 == exp2:
        return []

    if isConstant(exp1) and isConstant(exp2):
        if exp1 != exp2:
            print(f"{exp1} and {exp2} are constants. Cannot be unified")
            return []

    if isConstant(exp1):
        return [(exp1, exp2)]

    if isConstant(exp2):
        return [(exp2, exp1)]

    if isVariable(exp1):
        return [(exp2, exp1)] if not checkOccurs(exp1, exp2) else []

    if isVariable(exp2):
        return [(exp1, exp2)] if not checkOccurs(exp2, exp1) else []

    if getInitialPredicate(exp1) != getInitialPredicate(exp2):
        print("Cannot be unified as the predicates do not match!")
        return []
```

```
    attributeCount1 = len(getAttributes(exp1))
    attributeCount2 = len(getAttributes(exp2))
    if attributeCount1 != attributeCount2:
        print(f"Length of attributes {attributeCount1} and {attributeCount2} do not match.
Cannot be unified")
        return []

    head1 = getFirstPart(exp1)
    head2 = getFirstPart(exp2)
    initialSubstitution = unify(head1, head2)
    if not initialSubstitution:
        return []
    if attributeCount1 == 1:
        return initialSubstitution

    tail1 = getRemainingPart(exp1)
    tail2 = getRemainingPart(exp2)

    if initialSubstitution != []:
        tail1 = apply(tail1, initialSubstitution)
        tail2 = apply(tail2, initialSubstitution)

    remainingSubstitution = unify(tail1, tail2)
    if not remainingSubstitution:
        return []

    return initialSubstitution + remainingSubstitution
def main():
    print("Enter the first expression")
    e1 = input()
```

```
    print("Enter the second expression")
    e2 = input()
    substitutions = unify(e1, e2)
    print("The substitutions are:")
    print([' / '.join(substitution) for substitution in substitutions])
main()
```

OUTPUT:



LAB 9: Convert given first order logic statement into Conjunctive Normal Form (CNF).

CODE:

```
import re
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return [m for m in str(matches) if m.isalpha()]
def getPredicates(string):
    expr = '[a-z~]+\([A-Za-z,]+\)'
    return re.findall(expr, string)
def DeMorgan(sentence):
    string = ''.join(list(sentence).copy())
    string = string.replace('~~','')
    flag = '[' in string
    string = string.replace('~[','')
    string = string.strip(']')
    for predicate in getPredicates(string):
        string = string.replace(predicate, f'~{predicate}')
    s = list(string)
    for i, c in enumerate(string):
        if c == 'V':
            s[i] = '^'
        elif c == '^':
            s[i] = 'V'
    string = ''.join(s)
    string = string.replace('~~','')
    return f'[{string}]' if flag else string
```

```
def Skolemization(sentence):
    SKOLEM_CONSTANTS = [f'{chr(c)}' for c in range(ord('A'), ord('Z')+1)]
    statement = ''.join(list(sentence).copy())
    matches = re.findall('[∀∃].', statement)
    for match in matches[::-1]:
        statement = statement.replace(match, '')
        statements = re.findall('\[\[^]]+\]]', statement)
        for s in statements:
            statement = statement.replace(s, s[1:-1])
        for predicate in getPredicates(statement):
            attributes = getAttributes(predicate)
            if ''.join(attributes).islower():
                statement = statement.replace(match[1],SKOLEM_CONSTANTS.pop(0))
            else:
                aL = [a for a in attributes if a.islower()]
                aU = [a for a in attributes if not a.islower()][0]
                statement = statement.replace(aU, f'{SKOLEM_CONSTANTS.pop(0)}({aL[0] if len(aL) else match[1]})')
    return statement
def fol_to_cnf(fol):


    statement = fol.replace("<=>", "_")
    while '_' in statement:
        i = statement.index('_')
        new_statement = '[' + statement[:i] + '=>' + statement[i+1:] + ']^['+ statement[i+1:] + '=>' + statement[:i] + ']'
        statement = new_statement
    statement = statement.replace("=>", "-")
    expr = '\[([^]]+)\]'
    statements = re.findall(expr, statement)
```

```
for i, s in enumerate(statements):
    if '[' in s and ']' not in s:
        statements[i] += ']'
for s in statements:
    statement = statement.replace(s, fol_to_cnf(s))
while '-' in statement:
    i = statement.index('-')
    br = statement.index('[') if '[' in statement else 0
    new_statement = '~' + statement[br:i] + 'V' + statement[i+1:]
    statement = statement[:br] + new_statement if br > 0 else new_statement
while '~∀' in statement:
    i = statement.index('~∀')
    statement = list(statement)
    statement[i], statement[i+1], statement[i+2] = '∃', statement[i+2], '~'
    statement = ''.join(statement)
while '~∃' in statement:
    i = statement.index('~∃')
    s = list(statement)
    s[i], s[i+1], s[i+2] = '∀', s[i+2], '~'
    statement = ''.join(s)
statement = statement.replace('~[∀','[~∀')
statement = statement.replace('~[∃','[~∃')
expr = '(~[∀V∃].)'
statements = re.findall(expr, statement)
for s in statements:
    statement = statement.replace(s, fol_to_cnf(s))
expr = '~\[[^]]+\]'
statements = re.findall(expr, statement)
for s in statements:
```

```
        statement = statement.replace(s, DeMorgan(s))
    return statement
def main():
    print("Enter FOL:")
    fol = input()
    print("The CNF form of the given FOL is: ")
    print(Skolemization(fol_to_cnf(fol)))
main()
```

OUTPUT:

```
Install the latest PowerShell for new features and improvements! https://aka.ms/PSWindows

PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\N_AI\FOL.py"
Enter FOL:
∀x[∃z[loves(x,z)]]
The CNF form of the given FOL is:
[loves(x,B(x))]
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2>
```

LAB 10: Create a knowledgebase consisting of first order logic statements and prove the given query using forward reasoning.

CODE:

```
import re


def isVariable(x):
    return len(x) == 1 and x.islower() and x.isalpha()
```

```
def getAttributes(string):
    expr = '\([^)]+\)'
    matches = re.findall(expr, string)
    return matches

def getPredicates(string):
    expr = '([a-z~]+)\([^&|]+\)'
    return re.findall(expr, string)
class Fact:
    def __init__(self, expression):
        self.expression = expression
        predicate, params = self.splitExpression(expression)
        self.predicate = predicate
        self.params = params
        self.result = any(self.getConstants())

    def splitExpression(self, expression):
        predicate = getPredicates(expression)[0]
        params = getAttributes(expression)[0].strip('()').split(',')
        return [predicate, params]

    def getResult(self):
        return self.result

    def getConstants(self):
        return [None if isVariable(c) else c for c in self.params]

    def getVariables(self):
        return [v if isVariable(v) else None for v in self.params]
```

```
    def substitute(self, constants):
        c = constants.copy()
        f = f"{self.predicate}({','.join([constants.pop(0) if isVariable(p) else p for p in self.params])})"
        return Fact(f)
class Implication:
    def __init__(self, expression):
        self.expression = expression
        l = expression.split('=>')
        self.lhs = [Fact(f) for f in l[0].split('&')]
        self.rhs = Fact(l[1])

    def evaluate(self, facts):
        constants = {}
        new_lhs = []
        for fact in facts:
            for val in self.lhs:
                if val.predicate == fact.predicate:
                    for i, v in enumerate(val.getVariables()):
                        if v:
                            constants[v] = fact.getConstants()[i]
                    new_lhs.append(fact)
        predicate, attributes = getPredicates(self.rhs.expression)[0], str(getAttributes(self.rhs.expression)[0])
        for key in constants:
            if constants[key]:
                attributes = attributes.replace(key, constants[key])
        expr = f'{predicate}{attributes}'
        return Fact(expr) if len(new_lhs) and all([f.getResult() for f in new_lhs]) else None
```

```
class KB:
    def __init__(self):
        self.facts = set()
        self.implications = set()

    def tell(self, e):
        if '=>' in e:
            self.implications.add(Implication(e))
        else:
            self.facts.add(Fact(e))
        for i in self.implications:
            res = i.evaluate(self.facts)
            if res:
                self.facts.add(res)

    def query(self, e):
        facts = set([f.expression for f in self.facts])
        i = 1
        print(f'Querying {e}:')
        for f in facts:
            if Fact(f).predicate == Fact(e).predicate:
                print(f'\t{i}. {f}')
                i += 1

    def display(self):
        print("All facts: ")
        for i, f in enumerate(set([f.expression for f in self.facts])):
            print(f'\t{i+1}. {f}')
def main():
```

```
    kb = KB()
    print("Enter KB: (enter e to exit)")
    while True:
        t = input()
        if(t == 'e'):
            break
        kb.tell(t)
    print("Enter Query:")
    q = input()
    kb.query(q)
    kb.display()
main()
```

OUTPUT:

```
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2> python -u "c:\Users\PUNEETH K\OneDrive\Desktop\LAB_2\N_AI\Forward.py"
Enter KB: (enter e to exit)
missile(x)=>weapon(x)
missile(M1)
enemy(x,America)=>hostile(x)
american(West)
enemy(Nono,America)
owns(Nono,M1)
missile(x)&owns(Nono,x)=>sells(West,x,Nono)
american(x)&weapon(y)&sells(x,y,z)&hostile(z)=>criminal(x)
e
Enter Query:
criminal(x)
Querying criminal(x):
        1. criminal(West)
All facts:
        1. criminal(West)
        2. sells(West,M1,Nono)
        3. weapon(M1)
        4. owns(Nono,M1)
        5. missile(M1)
        6. hostile(Nono)
        7. enemy(Nono,America)
        8. american(West)
PS C:\Users\PUNEETH K\OneDrive\Desktop\LAB_2>
```